A directionally based bandwidth reservation scheme for call admission control

Conference or Workshop Item

A DIRECTIONALLY-BASED BANDWIDTH RESERVATION SCHEME FOR CALL ADMISSION CONTROL

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Abstract– This paper proposes a new advanced *Call Admission Control* (CAC) strategy involving for the first time, a bandwidth reservation scheme that is influenced by the *direction* attribute of a mobile terminal (MT). Aside from the *Quality-of-Service* (QoS) parameters, the *direction* attribute plays a key role in efficiently reserving resources for MTs supporting multimedia communications for different QoS classes. The framework for a direction-based CAC system is entirely distributed and may be viewed as a message passing system, where MTs inform their neighbouring base stations (BS) not only of their QoS requirements, but also of their mobility parameters. The base stations then predict future demand and reserve resources accordingly, only admitting those terminals that can be adequately supported. The bandwidth reservation scheme proposed in this paper, integrates the *direction* attribute into the conventional Guard Channel (GC) scheme. Simulation results prove that this new scheme offers significant improvements in both Call Blocking Probability (CBP) and bandwidth utilization, under a variety of differing traffic conditions.

Keywords– *QoS, Mobile Multimedia Communication, Call Admission Control, Handoff, Guard Channel, SimuLink.*

I. INTRODUCTION

Third generation (3G) wireless technology will support multimedia traffic at a target transmission rate of up to 2Mbps for static mobile users and 384 Kbps for high mobility users [3]. The unprecedented growth and demand for mobile networks to support both data and real-time multimedia traffic, has meant that while best-effort services suffice for datagram traffic, the usability of real-time multimedia applications is vastly improved if the underlying network can provide a guaranteed quality of service (QoS). In wireline networks, admission control and bandwidth allocation schemes offer users in principle; such guarantees, but for mobile networks, the scarcity of bandwidth and channel imperfections, means the QoS provisioning problem is far more challenging. Unlike their wired counterparts, communication entities in mobile networks change their connectivity via handoff, when they move from one cell to another. The limited bandwidth resources in mobile multimedia system, means efficient Call Admission Control (CAC) and resource reservation (RR) schemes are required to maintain the desired QoS.

Admission Control refers to the task of deciding if a connection should be admitted into and supported by the network. Admission control is necessary for real time continuous media connections since the amount of resources requested by these connections may not match the level of resources available at the time of the connection setup. Admitting a connection into the network is tantamount to a contract between the network and the connection, which should be maintained for the duration of the connection [1][7].

In most admission schemes, it is typical to deny services to a new call whose request for resources cannot be met by the network. In this case, the call is said to be blocked. In mobile networks, an important QoS parameter is the *Call Blocking Probability* (CBP) denoting the probability that a new connection request will be denied admission to the network. A similar situation arises when an established connection in one cell attempts to migrate into a neighbouring cell (i.e., a handoff is attempted). If the new cell cannot support the level of resources required by the connection, the handoff is denied and the connection is dropped. An additional important consideration is the degree to which the network makes effective use of bandwidth-unquestionably its most valuable yet scarce resource. This is quantified by the *Bandwidth Utilization* parameter, which expresses the ratio between the amount of bandwidth used by various applications admitted into the network and either the total bandwidth requested or the total bandwidth available, whichever is smaller [2][4]. Keeping the CBP low while at the same time maximizing the bandwidth utilization under the condition of continuous connection is one of the most important challenging tasks facing protocol designers [7][13].

Maximising the available bandwidth is a major challenge in mobile multimedia communications and has been intensively studied in recent times [5][7][9][10]. For uninterrupted handoff procedure, researchers have proposed reserving bandwidth in all neighbouring and other cells which the mobile can possibly visit. Such schemes are clearly very inefficient as the number of cells reserving bandwidth could be significant for a mobile which may be either stationary or visits only a few cells. The solution proposed in this paper, is based on a direction-based scheme and solves

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this problem by reserving bandwidth based on the predicted direction of mobility.

The paper is organized as follows. Section II surveys related work and confirms the originality of this new scheme. Section III describes the proposed scheme in detail, while Section IV presents the simulation models. In Section V, simulation results are presented to analyse the performance of the proposed scheme. Finally, some concluding remarks are given in Section VI.

II. PREVIOUS WORK AND SYSTEM DESIGN OBJECTIVES

Any CAC strategy is by its very nature, much more complicated in a mobile network. An accepted call originated in the current cell may have to be handed off to another cell before completion of its tasks. During this process, the call may have to gain a channel in the new cell to continue its service as otherwise the call must be dropped. Thus, new calls and handoff calls are treated differently in all CAC strategies. In the Guard Channel (GC) scheme [5], handoff calls are normally assigned a higher priority than new calls. This scheme reserves a portion of channel for handoff calls; whenever a channel is released, it is returned to the common pool of channels. However, it has a number of deficiencies, in particular, the GC scheme increases the call blocking probability by reserving bandwidth in many cells (see Figure 1) for a given call. Obviously not all cells reserving bandwidth will be visited which in turn means that it may not be able to potentially meet different QoS requirements. [12].

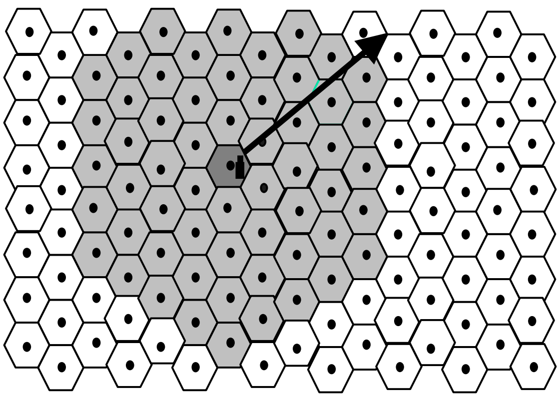

Figure 1: Mobile station reserving bandwidth in all neighbouring cells.

In Queuing Priority (QP) schemes, calls are accepted whenever there are free channels. When all channels are busy, new calls are queued while handoff calls are blocked [3]. New calls are blocked while handoff calls are queued [11], or all arriving calls are queued with certain rearrangements in the queue [5]. These schemes are not suitable for multimedia communications for the reason that large amounts of real-time data cannot be stored in the queue. Moreover, channels must be made available before time-out.

Some recent schemes of call admission control strategies like Rate-based Borrowing Scheme [7], Schemes based on Probabilistic Paging [13] are also not suitable for real time multimedia communications. Again this is due to the limited bandwidth as these schemes reserve bandwidth in all neighbouring cells of a mobile station as shown in Figure 1.

The fundamental drawback of all these schemes is that no consideration is given to either mobility status or the direction of mobility, i.e. a large number of cells may be reserved while the mobile may be stationary in a fixed cell or may move through only a very small portion of cells where channels are reserved for it, leading to wastage. Therefore, techniques for reserving bandwidth more intelligently should obviously play a vital role on efficiency measurement parameters for mobile multimedia communications.

The direction-based concept is based on the premise that "*every mobile terminal with an active wireless connection exerts an influence upon the cell in its direction of travel*." The coverage of direction-based concepts for a given active mobile mainly consists of the cell where the mobility is currently present and all adjacent cells in the direction of travel. Simulations prove that this mechanism is able to both reduce CBP and increase channel utilization.

III. PROPOSED DIRECTION BASED BANDWIDTH RESERVATION ALGORITHM

In the proposed scheme, it is assumed that mobile users monitor the mobility through its Signal-to-Noise Ratio (SNR) and requests a new connection or roams into a new cell, when necessary.

A. Interaction in Mobile Communication System

Mobile communication systems usually consist of three key elements: Mobile Terminal (MT), Base station (BS) and Main Telephone Switching Office (MTSO). Each active MT connects to one BS at a time. However, each BS will receive signals not only from its associated MTs but also from the MTs in the neighbouring cells. If the received SNR is higher than a threshold for an MT in neighbouring cells, based on the proposed direction based estimator function, a BS will send a report message to the MTSO to register itself as a handoff candidate of the MT. The SNR signal strength also provides each BS with distance information upon a MT, which is within the awareness range for that BS. Detailed propagation fading models can be found in [1].

B. Proposed direction based resource reservation (RR) estimator function

The proposed new direction-based resource reservation (RR) estimator function is founded on the observation that the BS in the direction of MT mobility has a higher probability to be required to allocate channels to a handoff MT in the near future. This probability decreases as the angle increases, so when the angle becomes 90^{o} or greater, it is zero. This is illustrated in Figure 2, where the base stations are constrained from reserving bandwidth whenever they are in the opposite direction to the mobility.

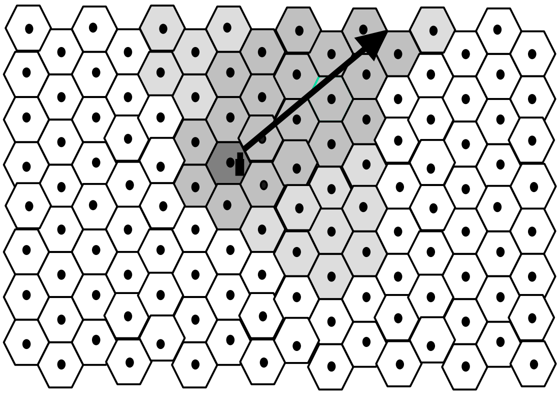

Figure 2: MT shows higher probability to go in the direction of mobility.

The non-linear estimator function for reserving bandwidth is defined in (1) which considers the direction of mobility and probable risk factor of suddenly changing direction without notice.

$$R_t = \begin{cases} 1, & \text{if } d \le R_c \\ 0, & \text{if } \cos\delta \le 0 \text{ and } d > R_c \\ \cos\delta, & \text{otherwise} \end{cases} \qquad (1)$$

where d is the distance from MT to BS, R_C is the radius of cell and δ is the angle of the direction from BS. Figure 3 explains the relevance of δ, where ***BA*** is the direction of mobility and C is the BS considering estimator for bandwidth reservation for the mobile residing in cell B.

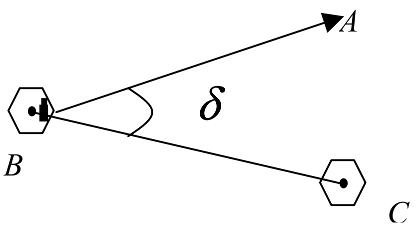

Figure 3: Graphical definition of δ

C. Proposed Resource Estimation and Call Admission Algorithm

For a new connection, the proposed scheme works as follows. An attempt is made to allocate the desired amount of bandwidth in the cell where the new connection is generated and reserve bandwidth in other neighbouring cells based on R_t. If the desire bandwidth is not available for allocation, then the call will be rejected (call block). The various steps in the algorithm for reserving bandwidth in different neighbouring cells is given in Figure 4 :

Step 1: if desired bandwidth is not available, then go to Step 5;

Step 2: if distance(BS,MT) < Radius_of_cell then reserve bandwidth for the call and go to Step 4;

Step 3: if **cosδ** > 0 then, reserve bandwidth with probability **cosδ**;

Step 4: Go back to Step 1 to reserve bandwidth for another call, if one exits;

Step 5: End;

Figure 4: Direction based bandwidth reservation (DBR) algorithm.

IV. SIMULATION MODEL DESCRIPTION

Discrete event simulations were conducted by using the Simulink in MATLAB 6.1.0.450, which is widely used for simulating both wired and wireless environments. Both a service model and the proposed DBR algorithm were implemented to analyse the effects of these call admission strategies under different traffic conditions.

Table I: Simulation Parameters.

Parameter	Value	Description
N	9	Number of cells in system
M	var	Number of mobiles in system
G_{on}	0.5	Probability of going on in the same cell
G_{out}	0.0001	Going out of network probability
S_t	var	Received signal strength
R_c	1000	Radius of the cell
V_{max}	34	Maximum velocity in meter/sec
λ	var	Mean call arrival rate
$1/\mu$	var	Mean talk time
G_{off}	0.01	Mobile off probability
V_s	0.1	Velocity sensitivity of MT
$1/\mu_{off}$	var	Mean off time
$1/\mu_{out}$	var	Mean out of network staying time

A cellular network consisting of closely packed hexagonal cells, using a fixed channel allocation scheme is considered, with each cell having a capacity of N channels. It is assumed that the arrival rate of new calls is a Poisson distribution with a rate of λ. Call duration time is exponentially distributed with the average call duration $1/\mu$ (i.e., connected calls terminate at a rate of μ). G_{on} is the probability of a mobile being on in same cell where the mobile previously went off. The objective of our DBR algorithm is to maximize the channel utilization, i.e., minimize new call blocking probability by reserving bandwidth only in the direction of mobility keeping certain precaution for abnormal change of direction, i.e., if the distance between MT and BS is less than radius of cell, then bandwidth is reserved for that MT.

Table I summarizes all the simulation parameters. The values for the simulation parameters are chosen carefully in order to closely represent realistic scenarios [3][10][13] and yet make the simulation feasible. Using the simulation model described above, the proposed scheme is evaluated. The performance measures obtained through the simulation are the blocking probability of new connections as well as the bandwidth utilization.

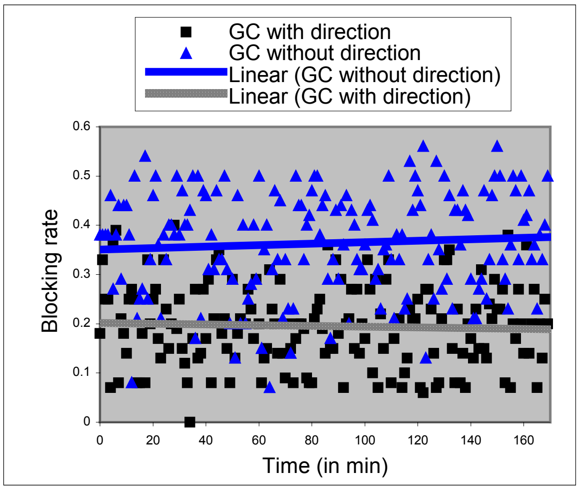

Figure 5: Blocking rate comparison with respect to time at a constant traffic load 14 calls/min.

V. SIMULATION RESULTS

Initially in any simulation, cells and mobile terminals are in an empty state. To avoid any error introduced due to this unrealistic initial condition, simulation results are collected only after the simulation reached a quiescent state. For example, to prepare the results presented in Figure 5, a simulation was carried out for 720 minutes; but data of only the last 170 minutes are analysed

Our proposed scheme is compared with the conventional GC scheme against call blocking rate and channel utilization.

A. Call Blocking Rate

To measure the impact of a scheme on call blocking rate, simulation must be carried out under a constant call traffic load. Figure 5 plots call-blocking rate of both the schemes against time at a constant traffic load of 14 calls/min. To analyse the data trends, a linear regression model is applied on both the data sets. The trend lines clearly show that the average call blocking rate of the proposed scheme (~18%) is significantly better than the same of the conventional GC scheme (~37%).

In Figure 6, call blocking rates of both the schemes are plotted against different call traffic load situations. It can easily be observed that the proposed scheme outperformed the conventional GC scheme for all traffic conditions. Moreover, the level of improvement increased with increasing traffic load.

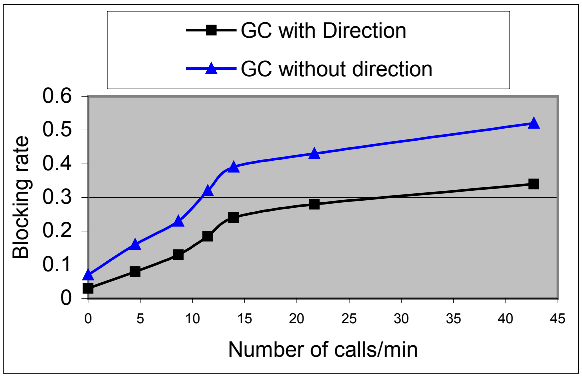

Figure 6: Comparison of blocking rates for different traffic conditions.

B. Channel Utilization

Figure 7 shows the impact on bandwidth utilization which is significant. The bandwidth utilization in the new proposed scheme is (~78%) compared with that of (~65%) for the conventional GC scheme for traffic loads of 14 calls/minute.

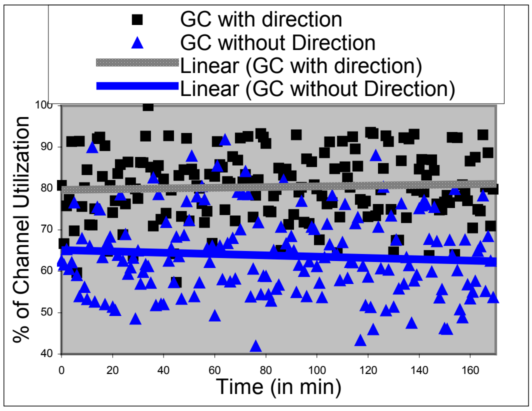

Figure 7: Channel utilization comparison with time at a constant traffic load 14 calls/min.

The Channel utilization under different traffic loads is shown in Figure 8. Channel utilization decreases with the increase of traffic loads both for the proposed scheme and conventional GC scheme. However, our proposed scheme shows better results in terms of bandwidth utilization under all different traffic conditions and the comparative performance also increases with the increase of call traffic load.

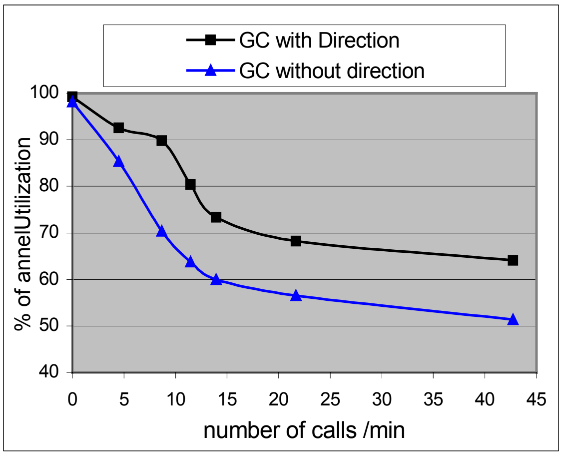

Figure 8: Comparison of channel utilization for different traffic conditions.

VI. CONCLUSIONS

This paper has presented a new direction-based bandwidth reservation (DBR) scheme which has the potential to be very useful in any mobile network application, where bandwidth is at a premium, such as in mobile multimedia communications. The efficiency of DBR occurs because it exploits both the direction and distance of a MT. Simulation results have proven the improvement achieved by using this new scheme.

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